# SOUTHERN AFRICA: FOOD SECURITY POLICY OPTIONS

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# REFLECTIONS ON TWO DECADES OF RESEARCH ON SORGHUM-BASED FARMING SYSTEMS IN NORTHERN NIGERIA AND BOTSWANA

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## INTRODUCTION

The subject assigned to us is a huge topic and has to be handled very selectively. Therefore, we only discuss issues which are directly related to food security. As was emphasised at last year's conference, there are two sides to food security; food availability and households having the resources to obtain food (Rukuni and Eicher, 1987). Both are now included in the SADCC policy for food security (Dhilwayo, 1987). While recognizing the critical nature of the linkage to macro policy, this paper focuses on the micro or household level. Also, rather than presenting detailed information on research activities and empirical findings, we make generalized statements about sorghum-producing households and farming systems patterns with the goal of deriving implications for future research.

The paper begins by comparing farming circumstances and sorghum production systems in northern Nigeria and Botswana. The comparison provides a background for characterising farmers' food security strategies. This is followed by a brief review of changes in research approaches that have occurred over the last 20 years in both countries. We propose that there is much complementarity between micro-level farming systems work and macro policy analysis in efforts to attain improved food security. On the basis of this perspective, we discuss in the fourth section some issues affecting the efficiency of future micro-level food security research.

## COMPARISON BETWEEN AREAS

In the interests of brevity, we compare northern Nigeria and Botswana only with reference to three general topics: farmer aspirations and constraints, farming systems management, and food security strategies. These topics are not mutually exclusive and there are of course several other relevant topics.

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More detail on the two areas can be found elsewhere (Baker, 1987; ATIP, 1986a; ATIP, 1986b; Norman, Simmons and Hays, 1982).

**Farmer aspirations and constraints**

There is a certain universality in the aspirations of farming families. In economic terms, farming families try to maximize utility (satisfaction) which increases with real income, but decreases with higher levels of effort and risk. Attempts to maximise this utility take place within a set of constraints. As a result, it generally is not differences in aspirations but differences in the constraints which lead to the most important differences in farming systems. Such differences can be grouped in a number of ways. One classification is as follows (Norman, 1982):

- o natural conditions (e.g., climate, soil, etc);
- o factor (resource) endowments and prices; and
- o market or support systems for inputs and outputs.

The farming systems used by rural people are determined by all of the above. The natural environment determines the necessary conditions for the presence of a farming system while the socioeconomic circumstances provide the sufficient conditions for the presence of a farming system. Thus, differences in sorghum-based farming systems between northern Nigeria and Botswana result from a combination of the natural environment and socio-economic circumstances.

Harshness of the natural environment

In both areas, the most severe farming problems generally stem from limitations imposed by a lack of water. The seasonality of rainfall and its low annual level impose serious constraints on growing crops, and result in major variations in the demand for labour. In this sense, Botswana farmers operate under a much harsher climatic regime than those in northern Nigeria.

Also in both areas, soils are generally of poor quality, suffering from phosphorus deficiencies and low levels of organic matter. Particularly in Botswana, soils tend to have a low water-holding capacity and are subject to crusting following heavy rains. Soil erosion is a major problem in both areas, but is perhaps more severe in Botswana where many fields have been continuously cultivated for several decades.

Botswana farmers face two temperature problems which are not as important in northern Nigeria. First, the months when most planting is concentrated, because there usually is the greatest rainfall, are also the hottest months. Soil temperatures often exceed the cardinal level for sorghum seedling viability. The second problem is the onset of cool nights

at the end of the season. If there are even short drought periods, during which sorghum stops growing, late January and February plantings may not have enough time to mature.

Variability in factor endowments

As summarized in Table 1, farmers in northern Nigeria and Botswana have significantly different factor endowments. Farming families tend to be smaller in Botswana. The size of the effective cropping labour force is even less relative to northern Nigeria than is suggested by family sizes. In Botswana, two-thirds of the active rural population are attending school, tending livestock, or engaged in off-farm wage employment. In contrast, Botswana farmers generally have more land, livestock, and fixed capital. Farms in Botswana usually range from 10-20 hectares, not including communal grazing areas, compared to less than five hectares in northern Nigeria. Moreover, Botswana farms consist of one or two contiguous blocks of land while those in Nigeria often are composed of scattered plots.

Most farmers in Botswana own one or more mouldboard ploughs and many own donkey carts. Because of a national equipment subsidy programme, farmers in parts of the country now also have purchased row planters and cultivators. In addition, Botswana farmers have a comparable range of hand tools and receptacles as those owned by Nigerian farmers.

Farming strategies can be significantly affected by the ability of farmers to withstand production shortfalls. Botswana farmers have a much greater ability to deal with crop failures because of their control of cattle assets. While many Botswana farmers do not own cattle, more than half are able to draw against their cattle inventories in the face of adverse circumstances, thereby stabilizing their standard of living.

National resource endowments can also affect farmers, as recent experiences in both Nigeria and Botswana have demonstrated. During the 1970s, oil revenues in Nigeria were used to fund numerous agricultural programmes. Such programmes have been severely affected by the fall in oil prices. In Botswana, government has used revenues from cattle and diamonds exports to subsidize farming families--substantially mitigating the most serious effects of the ongoing six-year drought.

Markets for inputs and outputs

In northern Nigeria, as in much of Africa, there are both formal and informal markets for inputs and outputs. Informal trade occurs among households and in periodic markets. The periodic markets facilitate inter-household trade and provide a channel for evacuating surplus production from rural to urban centres. Food items are available on an irregular basis and there is substantial seasonal price variation. There is limited trade in

**Table 1. Selected aspects of farming systems: Mahalapye area, Botswana and Zaria, Nigeria (1976).**

| | Mahalapye area[a] | Zaria[b] |
|---|---|---|
| Climate: | | |
| Rainfall (mm/year) | 470 | 110 |
| Rainfall > PET (months) | 0 | 4 |
| Length of growing season (months) | 6-7 | 5-6 |
| Farm Size: | | |
| Cultivated land (ha) | 5.1 | 3.2 |
| Total (ha) | 17 | 3.9 |
| Any irrigation? | No | Yes |
| Field fragmentation | No | Yes |
| People: | | |
| Religion | Christian | Moslem |
| Residences | Village, lands, cattlepost | One |
| Family size | 7.7 | 8.8 |
| Major "income" sources | Livestock, off-farm Beer brewing, remittances | Crops, off-farm smallstock |
| Cropping: | | |
| Major crops | Sorghum, cowpeas watermelons, maize groundnuts | Millet, sorghum |
| Mean sorghum yield (kg/ha) | 74 | 800 |
| Self-sufficient in cereals | No | Yes |
| System: | | |
| Power | Animal | Hand |
| Land preparation | Flat | Ridge |
| Planting system | Broadcast | Row |
| Sole/mixed crop | Mixed | Mixed |
| Weeding | 1 | 2-3 |
| Fertilizer | Little | Manure and inorganic |
| Livestock uses: | Sales, draught, transport, milk | Manure and Transport |
| Cropping labour (%)[c] | | |
| Family: Adult males | 19 | 72 |
| Adult females | 33 | 1 |
| Children | 15 | 9 |
| Hired: | 33 | 18 |
| Peak labour demand: | | |
| Main peak | Weeding | Weeding |
| Secondary peak | Harvesting | Harvesting |
| Male adult work time | | |
| Percent on: Family farm/s | 19 | 81 |
| Livestock | 53 | 5 |
| Off-farm | 28 | 34 |
| Total hours | 1034 | 1172 |

[a]1983. [b]1976. [c]Mahalapye percentages based on hours; Zaria based on days.
Sources: ATIP (1986a); Norman, Simmons and Hays (1982)

production inputs.

Following a pattern established during the colonial period, the Government of Nigeria has intervened extensively in agricultural markets (Norman, Simmons, and Hays, 1982). Many approaches have been tried for fertiliser distribution, but all have met with little success. Organized seed distribution was limited to cotton until the 1970s, resulting in limited use of improved varieties of most crops. Marketing boards exist for most commodities, but there have been many problems with the marketing board system.

In Botswana, local trade historically has been dominated by informal exchanges between households. Informal trades are made for labour, traction, gathered items, and household products on both a cash and barter basis. Interhousehold exchanges significantly increase the access of poor farming families to required production resources.

Complementing household exchanges, in Botswana there is a network of privately owned general traders which extends to essentially all villages. The general traders distribute imported agricultural commodities and other household goods to rural areas. Most of the items sold are either processed or manufactured, and are of nearly standardised quality. Prices are subject to a price control system based on wholesale prices and transport costs.

A recent study of the trading network in the Central Agricultural Region (Baker, 1987) showed that the trading network is making a major contribution to food security due to the provision of food commodities and, to a lesser extent, agricultural implements and fencing materials. Input availability is a problem in smaller villages, particularly for major implements, but reasonably priced transport is available. The availability and low prices of imported, milled food grains clearly affect farmers' incentives to invest in sorghum production. Thus, food security is increased through the marketing system, but the incentive to achieve food self-sufficiency is decreased.

Seed for sorghum and other crops is available through the Botswana Agricultural Marketing Board (BAMB) depots located in the larger villages. MAMB also announces guaranteed producer prices before the beginning of each season.

**Farming systems management**

Farmers in both areas have developed intricate farming systems that permit family labour utilization throughout the year and provide ways to profitably invest capital. However, there are some significant contrasts in farming systems management between the two areas.

Enterprise emphasis

In Botswana, rural people traditionally have been pastoralists while in northern Nigeria the emphasis has long been on crop cultivation. In addition to cultivating rainfed land, Nigerian farmers have also cultivated small amounts of land near rivers and streams that can be irrigated with simple irrigation systems. These traditional orientations continue to distinguish the areas.

In porthern Nigeria, crops still constitute a more important component of farm and household income than in Botswana. Income from crop production accounts for more than a two-thirds of the total income of most households (Malton, 1977). Off-farm occupations, primarily within the village, are an important labour activity, but account for only a quarter of household income.

In Botswana, crop production is the third or fourth most important source of income for most households--following livestock tending (and sales), wage employment, and beer brewing. Remittances from families members working outside the village also tend to be a more important source of income than crop production at least for poor households. During the ongoing drought, even transfers from the government have provided more real income for many households than has crop production

Despite the importance of livestock in Botswana, there tends to be less complementarity between livestock and crop enterprises than in Nigeria. Animals generally are kept in a separate area from where crops are gown. Thus, the role of livestock as a provider of manure in Botswana is minimal. In northern Nigeria, such complementarities are maintained through pastoralists corralling their cattle on the fields of crop cultivators.

While out-of-village wage employment is very important in Botswana, in-village off-farm income opportunities are poorly developed, compared to northern Nigeria. For example, traditional marketing systems which provide many employment opportunities in West Africa are virtually nonexistent in Botswana. The reasons for this are not clear. One major factor may be that there has been no "engine of growth" in Botswana to foster its development, in the form of crops produced for disposal. Participation in the Southern African Customs Union has also restricted opportunities for the development of rural small-scale industries.

Sorghum production practices

Farmers in both areas want to increase total production from their cropping enterprise, but are using different strategies for attaining it. Some of the key differences are as follows:

o In Botswana, the much larger amounts of land cultivated per family

member imply a land extensification (labour saving) farming systems management strategy. In northern Nigeria, farmers have more of a land intensification (yield-increasing) strategy.

- In Botswana, the prevalence of cattle led to the introduction of animal traction more than eight years ago. In contrast, in northern Nigeria most crop cultivation is done by hand, requiring more labour per unit area. Reflecting the tillage methods, ridging and hill planting systems are prominent in northern Nigeria, while in Botswana most crops are gown on the flat. Farmers simply broadcast the seed and plough it in.
- Fewer crops are (or can be) grown in the harsher climatic environment of Botswana. Thus, in northern Nigeria, farmers often grow different corps for sale than those that they consume. In Botswana, sorghum serves as the main food crop and cash crop. Relatively few farmers grow special crops just for sale. This means that sorghum plays a relatively more important role for farmers in Botswana than for those in northern Nigeria.
- Reflecting their intensification strategy, farmers in northern Nigeria use more chemical fertiliser, apply greater quantities of organic manure, and weed two to three times. In Botswana, farmers broadcast plant and plough as large an area as possible after each rain. Post-planting operations generally are confined to one weeding and bird scaring.
- The gender division of labour is substantially different between the two areas. In Botswana, adult females provide most of the labour for sorghum production, as well as for household maintenance activities. Males traditionally have been responsible for tending cattle. Animal traction ploughing, a task not commonly found in northern Nigeria, is the only arable farming activity which is dominated by men in Botswana. In contrast, males account for more than three-quarters of the labour for crop production in northern Nigeria.

As a result of the respective management systems, traditional sorghum yields are much lower in Botswana than in northern Nigeria. It should be emphasised that the management systems in both areas represent reasonable responses to the realities of the natural environments and socioeconomic circumstances.

**Food security strategies**

In light of the above area comparisons, it should not be surprising that farmers in the two areas have significantly different food security strategies.

Farmers in northern Nigeria depend on achieving a high degree of food self-sufficiency. Staple food grain supplies cannot be reliably obtained through market purchases. The limited amount of cash generated through

sales of crops such as cotton, or from off-farm within-village employment, is largely needed for nonfood household requirements. Nigerian farmers can and do produce more of their food than Botswana farmers, but are quire susceptible to food shortfalls. Therefore, there is a great incentive to increase investments in crop production if the investments provide a reasonable and reliable return. A major issue facing northern Nigerian farmers is the balance in investment between sorghum and other crops.

In contrast, farming families in Botswana have systematically tried to minimize the linkage between food production and food security. While the main objective of growing sorghum is to meet household food grain requirements (Baker, 1987), no households actually rely on food self-sufficiency. Instead, most food is purchased using cash from a combination of several sources. If the rains are good and a sufficient quantity of sorghum is produced, it is a welcome event. The money which would have been spent on food becomes available for other items. The food security strategy of Botswana farmers implies that capital or labour investments in sorghum production usually are not a top household priority. This poses a major challenge to technology development researchers.

## CHANGES IN RESEARCH APPROACHES

There are two complementary approaches to increasing the productivity of farming families and improving their food security situation.

- o Develop and disseminate relevant improved technologies, which enable households to use resources previously underutilized an/or increase the productivity of resources already being utilized.
- o Develop relevant policies (e.g., pricing systems) and support systems (e.g., extension, credit, improved input distribution programmes on the input side, and markets for the products produced). The development of relevant policies and support systems can entail a combination of macro- and micro-level research.

Both components are needed to facilitate increased agriculture productivity and improved food security. Which is relatively more important is location and time specific. In this section we characterise the research which has been conducted in order to facilitate the development of sorghum-based farming systems and discuss the need for a micro-macro balance in future research.

### Overview

Throughout Africa, there has been an evolution in the approaches used to address the needs of farming families over the last 20 to 30 years. This

evolution is described below. Until now, the later components listed generally have not replaced the earlier ones. Rather, the additional components were incorporated over time in response to perceived weaknesses.

1. Prior to the 1960s. There were two main thrusts to technology development research. Both primarily focused on boosting the output of export crops. One strategy emphasised crop-variety improvement, with the objectives of increasing yields and insect and disease resistance. There was a limited amount of agronomic research to develop recommendations on plant spacing, fertilisation, and other husbandry practices for the new varieties. The second component entailed the selective transferring of mechanical and biological technologies from areas with more productive farming systems. Beginning in the 1950, station based, inductive research to develop technologies adapted to the natural environment became important. Little was known about the functioning of local markets and support systems research was not viewed a high priority.
2. 1960s. In northern Nigeria, detailed quantitative studies were undertaken by social scientists with the aim of understanding the rationality of limited resource farmers within the socio economic environments in which they were operating. There usually was little interaction with station-based technical scientists. Social science research (focused on improving farming systems and food security) was still lacking in Botswana.
3. Mid-1970s and early-1980s. The popularisation of farming systems work took place with its emphasis on the diagnosis of existing farming systems; and the design, testing, and dissemination of relevant improved technologies. Emphasis during this period was increasingly placed on cooperation with experiment station based scientists and involving farmers as active participants in the process of developing relevant improved technologies. The emphasis shifted from collecting quantitative data to qualitative understanding. Towards the end of the period, increasing concern was expressed about building linkages with extension and policy makers.
4. Mid-1980s. Concern over food security issues is leading to an increasing emphasis on policy issues and macroeconomic analysis.

**Discussion**

During the past 26 years, tremendous progress has been made in the way research on farm productivity and food security issues is being conducted. As a result, our understanding of the determinants of food security has greatly increased. At this point, it is almost inconceivable that inter-disciplinary on-farm research could be discontinued. It also seems that no

one should have to argue for the importance of understanding existing farming systems.

One of the most important issues at present is what is an appropriate balance between micro research on farming systems and macro policy analysis. It is our belief that it would be a mistake if macro policy research became the sole focus--or even the primary focus--of food security analysis (and donor agency funding) in the late 1980s.

We believe that micro-level farming system work--encompassing both technologies and support systems--plays a vital complementary role to policy analysis in efforts to achieve improved food security. Changes in policy without changes in technology are unlikely to solve long-run problems of food security. Certainly the insights and data collected in farming systems work should be of value to food security personnel working at the macro-level.

## ISSUES AFFECTING FUTURE RESEARCH

Based on the assumption that micro-level farming systems work will continue, we now will discuss several insights from past farming systems work and derive implications for future food security-related research. As above, our emphasis is on the development of relevant technologies and support systems.

**Within area resource distribution**

The way in which resources are distributed within areas can critically influence the welfare of individual families. Although national statistics might indicate the average family can attain food security, aggregation can mask underlying inequalities that need to be addressed. There is in fact evidence from both northern Nigeria and Botswana that resources are unequally distributed, thereby resulting in unequal income distribution (Malton, 1977; CSO, 1976), Moreover, there is qualitative evidence that inequality may be increasing in the face of growing populations, periodic drought, and a breakdown of traditional egalitarian notions of shared poverty.

Inequalities in resources and income distribution lead to a number of consideration in micro-level food security research, six of which are the following:

- o On-farm versus off-farm income. Matlong (1977) produced cross-sectional income distribution data from an area slightly north of Zaria in northern Nigeria. He showed that incomes from farming activities were less variable than from off-farm sources. He further found that,

although in absolute terms incomes from farming activities were much lower for poorer families, farm incomes as a proportion of total incomes were higher. As a result, farming income contributed both to greater income and income equality.

In Botswana, the potential of crop farming in creating rural income and employment opportunities is recognised in national policy. However, cropping income is less stable than livestock production or wage employment. If poor farmers are to be helped by cropping activities, attention must be given to stabilising cropping income.

- Level of food consumption. Evidence from both northern Nigeria and Botswana shows that many rural families, particularly poorer families, do not feed themselves. For example, Matlon found 60% of the farming families did not produce enough or retain enough food to feed themselves. Richer households had income from other sources to purchase enough food to make up the deficit, but 20% of the poorer households did not.

  In Botswana, Baker (1987) showed that poorer families consume most food items less frequently. Less grain is consumed per person in poorer households and poor households are more dependent on purchased food. In general, those households which are poorer and consume less, also are the least successful crop farmers.
- Seasonal hunger. In the face of low income, seasonal hunger becomes a critical issue. Seasonal hunger is characterized by food availability being at its lowest level at a time when the demands of the agricultural cycle are highest; and cash resources are also at their lowest. The effect of the hungry gap, as it is sometimes called, on the physical constitution of the hungry are fairly obvious. During the peak of the agricultural cycle individual calorie and protein consumption is insufficient (Grant, 1970) and a loss of weight tends to occur. A potential for further debilitating effects is created, since the chances of contracting nutritionally-related diseases are increased and the resistance of the body to other illnesses is decreased (Chambers *et al*, 1979).
- Dependency relationships. Inequality and associated food access problems create a milieu in which poverty is sustained and deepened because of the development of dependency relationships. Chambers *et al.* (1979) have pointed out, for example, that such short-run problems of overcoming hunger through working on other peoples land for cash, or through borrowing money and pledging land, can lead to a ratchet effect with a downward spiral. As a result, commitments made to survive one year lead to a lower potential income in future years.
- Compromises in technical efficiency. There is substantial evidence

that differences in technical efficiency often stem less from managerial ability than from compromises made to deal with inadequate income and resources. For example, in northern Nigeria the urgent need for food and cash make it necessary for members of low income families to work at off-farm occupations, thereby forcing farmers to delay planting sorghum and millet and delay the first weeding (Malton et al, 1979). As a result, poorer household are disproportionally represented amongst the least technically efficient producers.

Comparable compromises are observed in Botswana. Nearly half the households rely on other households for traction resources. In order to gain access, dependent households have to provide cash or labour for ploughing the traction owner's field. In order to obtain cash for food as well as ploughing, some family members emigrate for wage employment. Therefore, whether paying in labour or cash, draught dependent households consistently end up ploughing later and often have less people available for weeding. The result is a significant inverse relationship between levels of sorghum production (due to yields and area ploughed) and household resources (Baker, 1987).

- Relevance of technical solutions. Water shortages is the over-riding constraint for most farmers in Botswana and for many farmers in northern Nigeria. There are alternative tillage and planting practices which address water shortages. Whether they can be implemented depends, to a great extent, on the resources farmers have at their disposal. For example, in Botswana it is critically important to ensure ploughing is done as soon as possible after rains, in order to make sure water is available for germination and plant growth (although some farmers do take the chance that germination will result from a post-planting rain). Obviously, timely ploughing is easier for a tractor-owning farmer than for a farmer who has to hire donkeys. The challenge is to develop relevant guidelines for poor farmers as well as for farmers having access to greater levels of resources.

**Increasing returns to the limiting factor**

Farmers clearly take into account the impact of interventions on their most limiting resources. One of the main lessons from farming systems work is that technology development research must also pay attention to which factors are most limiting for which farmers. Whether land or labour will be the more limiting factor will tend to be location specific. However, ratios of land and labour can be very crudely simplified into three possible situations:

- In areas of low population density, the peak demand period for labour is likely to be the major constraining factor on expanded output.

- o In areas of transition to high population densities, it is possible that both labour and land constraints will emerge. The peak demand period for labour will be a constraining influence and land will emerge as a problem because soil fertility will decline under population pressure. The possible dual nature of these constraints will be exacerbated by the increasing need, in order to sustain a satisfactory level of living, for farm families to spend more time in activities that require year around commitments--including off-farm income earning activities, as well as caring for livestock owned by the family. As land becomes more of a constraint, the value of livestock in contributing to maintaining soil fertility will become greater. However, the problem of feeding livestock will also become greater; and quite likely will involve a change to more labour intensive methods.
- o In areas of very high population density, where labour becomes surplus, land is likely to be the most constraining factor.

The relative factor ratios given above suggest two basic priorities in efforts to introduce relevant technologies; first, improving the productivity of labour at bottleneck periods, and secondly, improving the strategies--such as introducing mechanisation to solve the problem of seasonal labour bottlenecks and bio-chemical technology to increase land productivity--are too simplistic.

There are three key issues which must be considered when determining a strategy to address farmers' limiting factors.

First, interventions designed to increase the return to the most limiting factor indirectly affect the use and/or productivity of other factors. For example, labour-saving technologies such as herbicides or inter-row mechanical cultivation--if used to peak labour periods--can improve yields due to more timely field operations. Yield-increasing technologies (e.g., improved seed; fertiliser; pest, disease, and weed control; improved cultural practices; etc.) will--if there is no change in the power base--usually increase labour demands. Depending on the degree to which yields are increased, this can have either a positive or negative impact on labour productivity.

Second, multiple binding constraints can be present in a single area, particularly if resources are inequitably distributed. However, it is not easy in semi-arid areas to design technologies that result in an increase in both land and labour productivity. For example, in a number of improved crop technology packages examined in Northern Nigeria, the only one that increased the productivity of both land and labour in a spectacular way was maize.

In Botswana we have had even more problems identifying packages which relate to land and labour constraints. One possible technology is double-

ploughing, the first one of which is undertaken in order to permit more water to enter the profile and be available at planting on the second ploughing operation. Our research over five years has shown that farmers facing a land constraint can obtain 75% higher yields and increased farm profits by double ploughing. Returns to ploughing labour also tend to be higher with double ploughing. However, the data supporting double ploughing for farmers who face only a ploughing or weeding labour constraint, not a land constraint, are less convincing.

Third, a very obvious requirement is the necessity of fitting technologies together with the complementary support systems. For example, in northern Nigeria the maize technology mentioned above could only be adopted by farmers when the World Bank came in with a series of agricultural development projects that had good distribution systems for inputs and provided markets for the output. In Botswana, double ploughing is not easy to advocate currently, particularly for those farmers facing a labour limitation, since a current development programme is heavily subsidising single ploughing of the land. This subsidy is not available for a second ploughing and therefore the costs and returns to farmers are less favourable than they would be otherwise.

**Exploiting flexibility versus breaking constraints**

Limiting factors can be addressed either through breaking constraints or by exploiting flexibility that exists in current farming systems. For example, in northern Nigeria planting labour is a limiting factor. Farmers avoid the limitation by planting cotton after food crops have been planted. Although lower yields are obtained due to late planting, the climatic environment permits some return from late season labour and land that would otherwise be underutilised.

In Botswana farming systems there are many fewer opportunities for exploiting flexibility. For example, because of low yields, it was necessary to break a planting labour constraint by turning to animal traction. The area cultivated increased and now farmers are faced with a weeding labour constraint. The timing of weeding cannot be greatly shifted because early weeding interferes with ploughing and necessitates a second weeding, while late weeding conflicts with bird scaring and early harvesting. A good alternative for overcoming the limitation is to introduce row planting and mechanical inter-row cultivation. This would be what we term "breaking the constraint" rather than exploiting flexibility.

In general, breaking constrains can lead to substantial improvements. However, investments required for breaking constraints generally are much greater than those used in exploiting flexibility. Also, there are often

negative equity implications associated with a "breaking constraints" strategy. Therefore, it is desirable to pursue a balanced approach, even if the opportunities for exploiting flexibility appear to be limited.

We have made some progress following this strategy in Botswana. For example, we have tried to break the water limitation through new tillage systems, all of which require control of traction resources. At the same time, we have taken advantage of the fact that in many households female labour is underutilized during the ploughing and planting period to develop a recommendation that women should invest time in post-establishment stand management (thinning and hand gap filling). A more even plant population makes better use of limited amounts of soil moisture.

**Understanding the logic of farmers' practices**

There is plenty of evidence that farmers in both areas have devised ways of surviving in their high risk natural environments. Research on crop mixtures, carried out 26 years ago in northern Nigeria, showed quite clearly that attempts to improve food security should pay serious attention to farmers' existing strategies and practices.

Data collected on crop mixtures in northern Nigeria showed that the gross margin per hectare was between 60 and 70% higher for crop mixtures. Although the total labour input for growing crops in mixtures was higher than in sole stands, the return per person hour during the major labour bottleneck period (June/July) was 20% higher for crop mixtures. Therefore, mixed cropping not only alleviated the labour bottleneck, but also paid off in terms of returns to that limited seasonal labour. The results also showed that growing crops in mixtures gave a more dependable return. This is not altogether surprising since different crops have different growing cycles, differing demands on soil nutrients, different rooting habits, and different susceptibilities to insect and disease attacks. As a result, failure or partial failure of one crop can sometimes be counteracted by compensatory growth by another.

We are not proposing that growing crops in mixtures is always the best strategy. In fact, there is some evidence to the contrary in Botswana because secondary crops such as cowpeas tend to out compete sorghum for the limited water. However, farmers recognise this and tend to plant extremely low populations of secondary crops in their sorghum-based crop mixtures. From an agronomic standpoint, their mixtures are effectively sole sorghum plantings. However, the secondary crops do make a major contribution to dietary diversity and help stabilize production in years when the primary sorghum crop fails.

**The need for options and guidelines**

The more unpredictable the rainfall is, the more likely farmers will adjust their cropping strategies depending on how the year develops. In such environments (if not all environments), it is unlikely that a single strategy will work every year. Therefore, technical scientists need to think in terms of a number of options that can be suggested to farmers.

A closely related issue is the need for guidelines (auxiliary information). As Byerlee (1986) has argued, technical scientists have tended to concentrate on developing recommendations (prescriptive information). They often have not given guidelines on fallback strategies if the recommendation is not applied according to specifications, or extra information that can help extension staff and farmers adapt the recommendations to their own circumstances. Such auxiliary information is very important and needs to be incorporated in recommendations.

**Minimize the requirements for purchased inputs**

As indicated earlier, farmers in harsh climatic environment buffer their farming systems through off-farm enterprises and livestock activities. Thus, any proposed intervention must be evaluated in terms of whether the resources used for implementing that intervention could be better and more reliably invested in activities other than arable agriculture. For example, in Botswana, few farmers are willing to invest cash in crop production since relatively few perceive crop production as a reliable way to produce a farm income.

Unless governments are willing and able to subsidize agricultural production, agronomist may be best occupied in the development of practices that require relatively low levels of extra inputs. Similarly, plant breeders should concentrate relatively more on modifying the plant to fit the environment rather than expecting the environment to be modified to fit the plant, a strategy that was so spectacularly successful in the green revolution.

**Technology ladder and farmer subsidies**

Conventional wisdom is that there is a technology ladder, initially involving the use of divisible inputs such as improved seed and fertiliser, followed by pesticides ad herbicides, and then later by lumpier more indivisible inputs such as mechanisation. In areas of high population density where the land/labour ration is low, such strategies often are feasible; but in areas with high land/labour ratios, the first step up the technology ladder is likely to be labour-saving equipment. This is the case in Botswana where timeliness of operation is so important, and the first step for many farming

families is obtaining access to draught animals and a plough.

It is apparent in the very harsh environment of Botswana that, without draught animals and related equipment, there is relatively little that can be done to help farmers more reliably produce their food grain requirements. Therefore, improving access to draught power through the judicious use of pricing policy and support systems management can help the more disadvantaged farmers meet the preconditions to improved productivity.

The commitment necessary on the part of the government in providing lumpy inputs is relatively greater than providing divisible inputs. Therefore, the issue of subsidies for traction and equipment is an important area where there needs to be close coordination between technical scientists and policy analysts. When designing farmer assistance programmes, an important issue is ensuring equal access by male and female farmers. This issue is not discussed in this paper, but is quite important in Botswana.

**Sustaining land productivity**

As human and animal populations increase, pressures on the relatively fragile land base also increase. Soil conservation is important in sustaining the potential for food security. However, unfortunately the closer farming families are to subsistence levels of living, the more short-run their articulated needs inevitably become. Consequently, for soil conservation strategies to work, there must be a convergence between the short-run private interests of farmers and long-run societal interests. In certain situations, trees used as fodder and fuel can provide this convergence, but in general, such conservation can only be implemented through substantial levels of subsidisation and/or considerable political will.

In Botswana, a national conservation strategy is currently being developed. The strategies being suggested will cost considerable amounts of money. Also, the crucial issue of controlling cattle access on the communal grazing areas still remains unresolved. Cattle ownership is very skewed in Botswana and some of the individuals responsible for changing policy are the ones who stand to lose most from such controlled access. Thus, personal and political considerations are likely to influence policy decisions affecting the balance between private and societal interests.

**Balance between on-farm and off-farm opportunities**

As discussed above, farmers in northern Nigeria and Botswana engage in an intricate web of crops, livestock, and off-farm activities. Until now, we have addressed farm production, with an emphasis on staple food grain (sorghum) production.

Despite the focus of this paper on sorghum production, we believe it is necessary for policy analysts to have a wider perspective than simply the

adoption of technologies. Policy analysis and support systems improvement need to address the whole farming system. Off-farm employment is a great generator of employment and income. More explicit attention is needed on the part of many governments to employment in the informal sector in rural areas.

## CONCLUSIONS

By helping sorghum-producing families, who constitute the majority of families in Botswana and northern Nigeria, to produce more sorghum and engage in other income-earning activities, we can contribute significantly to their attaining food security.

Reflecting on the past two decades of research, it is apparent that many errors have been made in our attempts to help small farmers attain food security. But there has also been some progress in developing an understanding of research priorities.

From our experiences we are convinced that, in order to design and develop technologies that farmers are likely to adopt, it is necessary to put ourselves closer to the natural and socioeconomic environment in which they operated. This has perhaps been the greatest strength and contribution of farming systems work. Stemming from farming systems work, there has been a move away from monolithic technology packages and toward the increased targeting of practices.

Much progress is still required, particularly in developing relevant policies and support systems that complement the role of relevant technologies in improving the productivity and food security of farming families on a sustainable basis. Appropriate policies and support systems can widen the possible applicability of technologies developed to address heterogeneity in the natural and socioeconomic environment. Thus micro-level farming systems work and macro policy analysis are important complements in efforts to attain food security.

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